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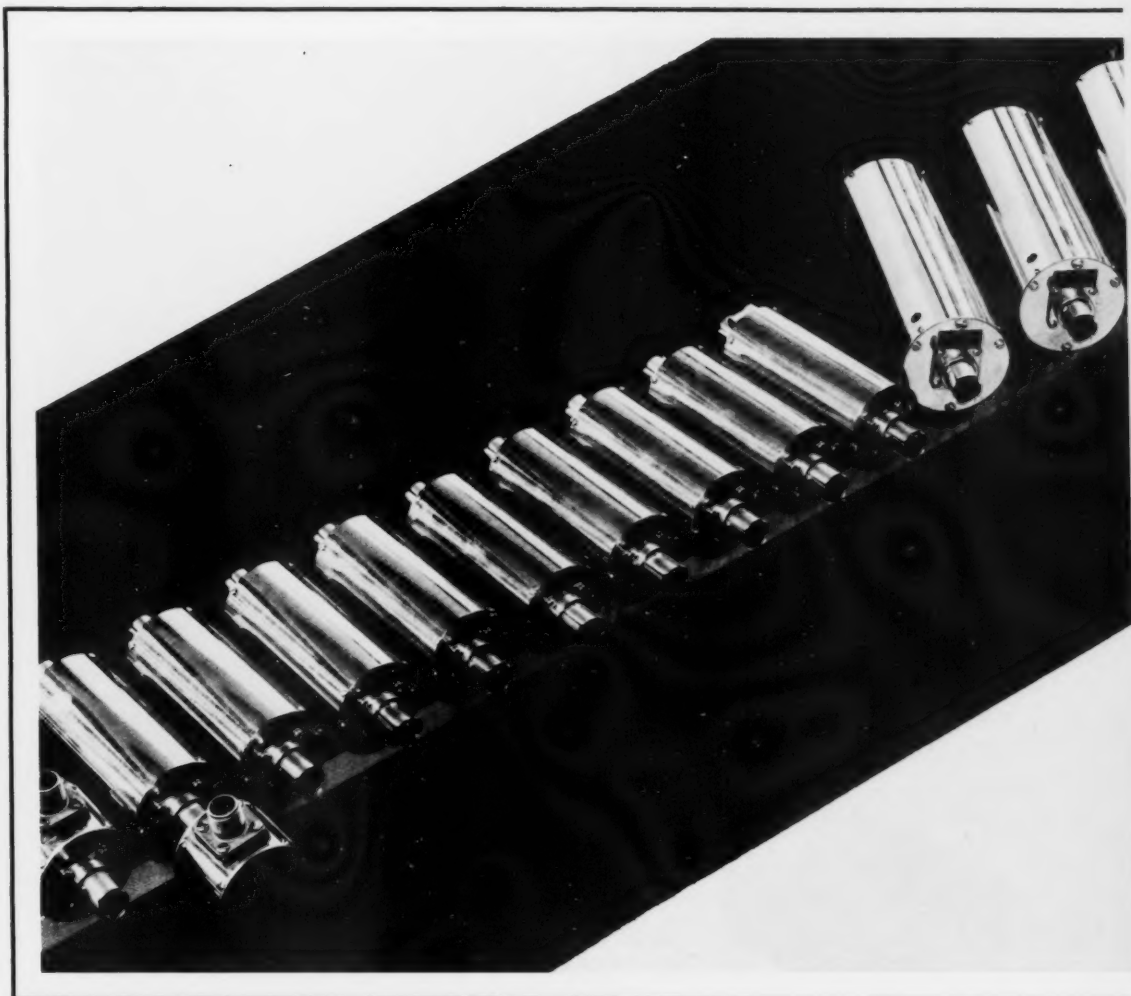
NATIONAL BUREAU OF STANDARDS

July/1967

Technical News Bulletin

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NATIONAL BUREAU OF STANDARDS

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U.S. DEPARTMENT OF COMMERCE

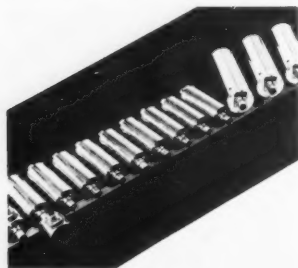
Alexander B. Trowbridge
Secretary

NATIONAL BUREAU OF STANDARDS

A. V. Astin, Director

CONTENTS

- 127 Physical properties related to crystallographic direction
- 129 Radiation detector gives precise low-temperature measurement
- 130 Accuracy of a-c voltage measurements increased
- 131 Building Systems Section formed
- 132 Standards and calibration
 - WWVB coordinated with DCF77
 - Calibration service now available for coaxial bolometer units fitted with 14-mm precision connectors
 - Standard frequency and time broadcasts
- 133 Standard reference materials
 - Oxygen in metals
 - Rubber standards
 - Plutonium metal
- 134 Rapid calibration of photodetector response
- 137 Conference and publication briefs
 - Industrial Research Institute visits Bureau
 - NBS hosts automotive engineers
 - American Ordnance Association meets at Gaithersburg
 - The Stress Corrosion of Metals
- 139 Ellipsometric-potentiostatic study of iron passivity
- 141 NSRDS news
- 144 JILA dedicates new facilities
- 144 Publications of the National Bureau of Standards



COVER

Accuracy better than 10 ppm (parts per million) in alternating voltage measurements is possible with these improved thermal voltage converters (see page 130).

Prepared by the NBS Office of Technical Information and Publications
Washington, D.C. 20234

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The National Bureau of Standards serves as a focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. For this purpose, the Bureau is organized into three institutes—

- The Institute for Basic Standards
- The Institute for Materials Research
- The Institute for Applied Technology

The TECHNICAL NEWS BULLETIN is published to keep science and industry informed regarding the technical programs, accomplishments, and activities of all three institutes.

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PHYSICAL PROPERTIES RELATED TO CRYSTALLOGRAPHIC DIRECTION



E. N. Farabaugh positions a calcium molybdate (CaMoO_4) crystal in the path of an x-ray beam.

■ Most physical properties of solids are anisotropic and must be referred to the proper crystallographic directions in the solid. Thus orientation must usually be taken into account if physical measurements on crystals are to be meaningful.

It is apparent that problems of crystal orientation are more complex than has at times been realized. A recent study at the NBS Institute for Materials Research has shown that values of some physical properties differ for mutually opposite directions although they are mirror images. This result implies that some electrical, mechanical, thermal, and magnetic data previously obtained for materials may be in error, perhaps through use of the wrong mathematical sign in the calculations. The study was carried out by Institute scientists E. N. Farabaugh, H. S. Peiser, and J. B. Wachtman, Jr., and was partly supported by the Atomic Energy Commission.

Working with calcium molybdate (a crystal with the scheelite crystal structure of calcium tungstate), the

investigators found that the positive [001] crystallographic direction differs from its opposite $[00\bar{1}]$ both of which are parallel to a major direction in the crystal lattice.¹ Their findings were shown to apply to all crystals having the scheelite structure and to many other crystals having particular symmetries in the crystal lattice. They also developed a method for easily determining the sense of the [001] direction in all scheelite-type crystals.

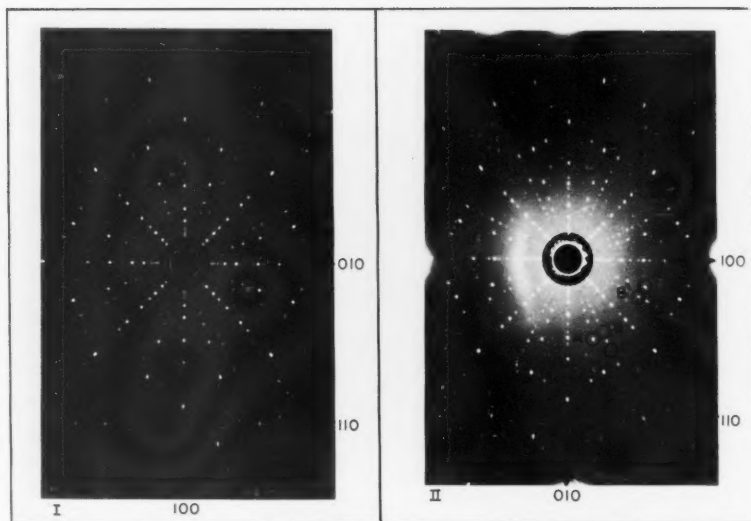
The standard technique for orienting crystals is the Laue back-reflection x-ray method. In this technique an x-ray beam is reflected from the crystal planes and the diffracted x-ray beams are recorded on a photographic film. The pattern on the film consists of regular patterns of spots, which correspond to various crystallographic planes in the lattice. Ordinarily a distinction is not made between equivalent lattice planes. This investigation has shown, however, that in certain cases such a distinction is required.

To understand the distinction made by the study, the reader must visualize

the rectangular (xyz) coordinate system that is ordinarily imagined to be attached to the crystal lattice. The axes of this coordinate system coincide with the major crystallographic directions in the lattice. In calcium molybdate the positive z-axis is placed along the positive [001] direction. As the xyz coordinates form a right-handed system, an observer at the origin of the coordinate system would see different surroundings when looking in the positive z-direction than when looking in the negative direction. This difference is notable in scheelite-type crystals where the xy plane perpendicular to the z-direction is a mirror plane. (A mirror plane "reflects" a clockwise rotation around the positive z-axis so that an observer at the origin looking in the opposite direction would see it as a counterclockwise rotation.) Thus, if particular atoms in the crystal structure form some helical sequence around the positive [001] direction, this sequence of atoms will be reversed to an observer at the origin looking in the opposite direction. The magnitude and sign of some physical

continued

Back-reflection x-ray diffraction photographs (normal to $[001]$) of calcium molybdate crystals display the diffraction patterns obtained when the x-ray beam enters from opposite surfaces. The circled diffraction spots indicate the reflections of clearly unequal intensities with the intensity of $A > A'$, the intensity of $B' > B$, the intensity of $C' > C$, and the intensity of $D > D'$.



PHYSICAL PROPERTIES

continued

properties in the crystal depend on the location of these atoms and thus will be different for measurements made in the positive or negative directions.

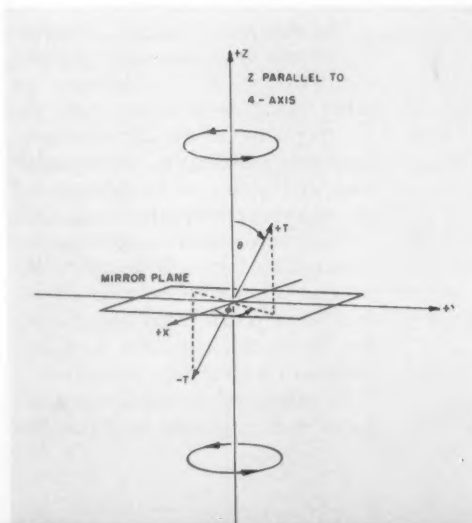
Many of these physical properties are tensor quantities of higher than second rank. Such properties as electrical and thermal conductivity, magnetic susceptibility, thermoelectricity, thermal expansion, and Peltier heating are examples of second rank tensor properties which are not affected, while those of higher rank include piezoelectric effects, electro-optical effects, and elastic compliances and constants. To understand which properties can be influenced by the difference between crystal directions, each property must be investigated for the individual crystal symmetries. In this study, for example, it has been found that certain elastic coefficients of calcium molybdate are dependant upon the differences between the positive and negative $[001]$ directions.

The investigation also showed that an examination of the x-ray photographs enabled a distinction to be made between the positive and nega-

tive $[001]$ directions for scheelite-type crystals. It was found that several crystallographic planes differed in diffraction intensity from other planes that were equivalent planes in the lattice but with the x and y intercepts interchanged. Four pairs of these planes were found to have reflection intensity ratios much different from unity. A simple inspection of the x-ray photographs showed the difference in the intensity of these pairs when the incident x-rays were approximately parallel to the $[001]$ direction. Changing the direction of the x-ray beam from $[001]$ to the $[00\bar{1}]$ crys-

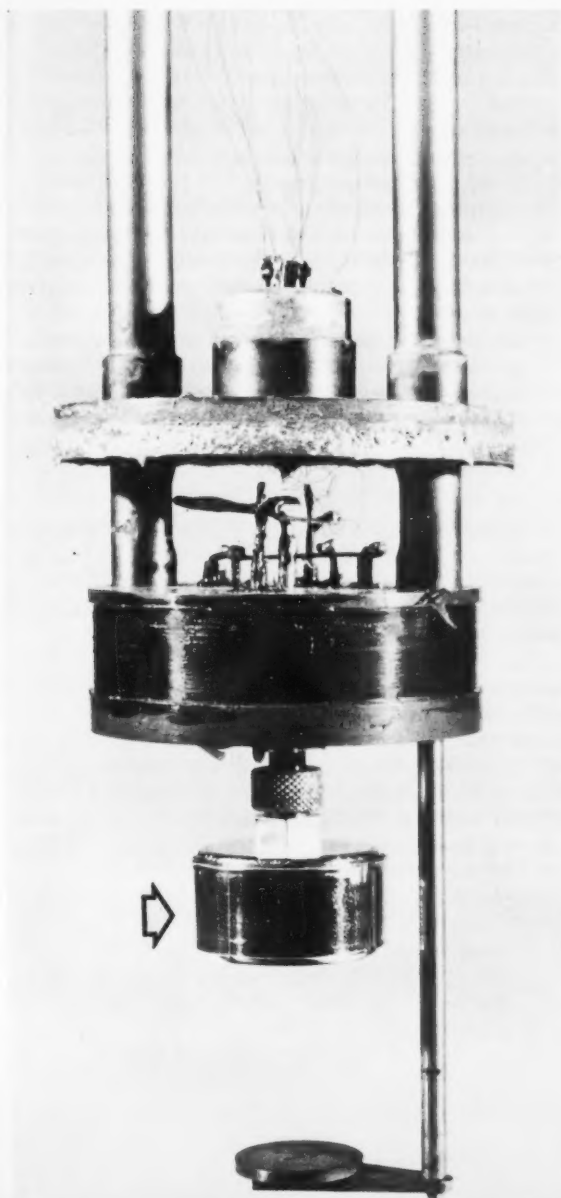
tal direction interchanges the intensities of the pairs of spots. A calculation was made to determine which of these pairs was brighter for either the positive or negative direction, and the sense of the $[001]$ direction was then determined directly from the photographs.

¹ For further technical details, see Orientation of calcium molybdate (CaMoO_4) and other single crystals having the scheelite structure, by E. N. Farabaugh, H. S. Peiser, and J. B. Wachtman, Jr., J. Res. NBS 70A (Phys. and Chem.), No. 5, 379-384 (1966). See also J. B. Wachtman, Jr., W. S. Brower, S. Spinner, and E. N. Farabaugh, Bull. Am. Ceram. Soc. 46, No. 3, 285 (April 1967).



Schematic axial representation illustrating crystallographic point group $4/m$. Note there is no mirror plane parallel to z ; therefore, the $+z$ and $-z$ directions are distinguishable.

RADIATION DETECTOR GIVES PRECISE LOW-TEMPERATURE MEASUREMENT



■ Many scientific experiments are conducted at very low temperatures. Studies of rocket fuel, superconductivity, and of solid-state components for use in outer space require measurements of temperature down to 2 °K.

In an effort to obtain better accuracy and precision at these temperatures W. R. Dodge, S. R. Domen, D. D. Hoppes, and A. T. Hirshfeld of the NBS Institute for Basic Standards recently adapted a silicon radiation detector to low-temperature thermometry.¹ The device gives stable, high-precision temperature measurements and is well suited for incorporation into a low-temperature-servo system.

The thermometer is based on the finding that when the temperature is sufficiently lowered, the product kT becomes much less than the ionization energies of the impurities in a silicon radiation detector. This results in a sharp, well-defined transition in the detector depletion depth occurring for all detector bias fields greater than approximately 100 volts/cm. The temperature at which the transition in depletion depth occurs is independent of the usual thermodynamic variables and depends only on the detector impurity concentration and ionization energy. Thus, pulse height is directly related to temperature.

The thermometer consists of a sensor, amplifier, integral discriminator, and scaler. The silicon radiation detector and a small mass of bismuth 207, polonium 210, or other suitable radioactive material, are mounted in a metal casing to provide a compact low-temperature sensor. The sensor output pulses, produced by the detector in response to the particles emitted by the radioactive mass, are transmitted over a coaxial cable to a temperature-indicating circuit. In the indicating circuit the pulses are amplified in a suitable pulse amplifier; discriminated as to pulse height, and if passed by the discriminator, counted by a scaler. Therefore, a series of detectors designed to detect pulses representing different temperatures, provide a multivalued low-temperature thermometer.

The principle upon which the thermometer is based also makes the device ideally suited for temperature detection and control. By using detectors designed to pass pulses representing different temperatures, the device may be used in a servo system to signal when the temperature is above or below that desired.

Preliminary tests at NBS indicate that the thermometer is accurate to 0.1 °K in the temperature range from 25 down to 10 °K. However, the investigators are still in the process of evaluating the complete capabilities of the thermometer.

¹ For further details, see Low temperature solid state thermometer, by W. R. Dodge and S.R. Domen, NBS Tech. Note 287, 23-25 (1966).

Low-temperature thermometer utilizes a silicon radiation detector (arrow) to obtain precision measurements.

ACCURACY OF A-C VOLTAGE MEASUREMENTS INCREASED

■ Recent advances in operational amplifiers and inductive voltage dividers have made possible wide-range a-c voltage standards (calibrated sources) with increased linearity and day-to-day stability. These improved power sources have in turn created a need for better accuracy in basic ac-dc transfer standards than the 0.01 to 0.02 percent previously available.

In a continuing program to obtain better ac-dc transfer measurement,¹ F. L. Hermach and E. S. Williams of the NBS Institute for Basic Standards have developed thermal voltage converters with ac-dc transfer accuracy better than 10 ppm (parts per million) at audio frequencies. In addition, they have developed a technique for comparing thermoelements* to a precision of 2 ppm. This has resulted in a-c measurements with accuracies 10 times better than were previously available.

The d-c standard cell and one-ohm resistors are the most stable electrical standards available. However, these d-c standards cannot be used for measuring alternating current directly. At the Bureau a-c measurements are made by comparison to d-c standards by means of thermoelements and thermal voltage converters as transfer devices.

Thermoelements

Fourteen thermoelements (TEs) form the present Bureau reference group for ac-dc difference. Twelve of the TEs (from four manufacturers) are of conventional design with heaters of modified nickel-chromium alloys that have low thermoelectric effects. The two other TEs are of a radically different design having many thermocouples (40 or more) attached to a bifilar heater. These were obtained from their inventor, F. J. Wilkins of the National Physical Laboratory in England.

In the technique used, TEs are evaluated in pairs (reference TE and test TE) with an emf-comparator to determine

the differences in their ac-dc transfer performance. The emf-comparator consists of two resistors, a millivolt potentiometer and two galvanometers as detectors. With the desired current or voltage applied, the resistors are adjusted in a preliminary balance to obtain a near null on one detector (D_1). Then, in regular succession, alternating, direct, and reversed direct and alternating currents are applied to the TEs at nearly equal time intervals and without changing the resistances. In each case the current is adjusted to obtain the same output emf from the test TE using the millivolt potentiometer (P) and detector (D_2). The resulting deflections are observed on the other detector (D_1). The relative ac-dc difference may then be computed from the difference between the average deflections obtained with a-c and d-c currents and a known sensitivity factor for D_1 .

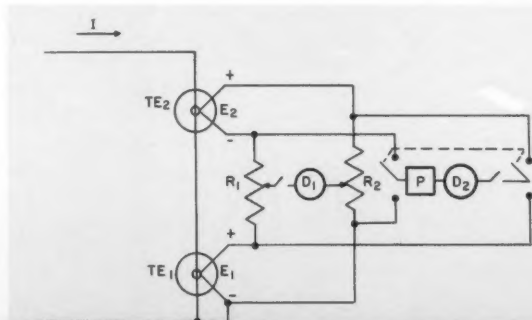
Calculations indicate that errors in TE comparisons from all known sources, should not exceed 2 ppm at audio frequencies, and should be even less for the Wilkins TEs. Tests have also shown that the average of the 12 conventional TEs agrees with that of the two others within 2 ppm.

Thermal Voltage Converters

A thermal voltage converter (TVC) consists of a thermoelement of low current rating with an associated resistor connected in series. TVCs can be used for ac-dc difference calibrations of similar devices, or to make accurate a-c measurements with appropriate d-c standards.

The voltage converters designed at NBS consist of one or more cylindrical metal-film resistors in a coaxial metal cylinder that can be connected in series with one of two 5-mA TEs mounted in separate cylinders. Adjacent ranges of these TVCs can be compared with greater certainty than could be done for previous converters that had integrally mounted TEs. The ac-dc errors from the reactances of the resistors can be calculated, at least roughly,

Schematic drawing of the emf comparator used in intercomparisons of thermoelements and adjacent ranges of thermal voltage converters.



from the simple geometry. They should be less than 1 ppm at audio frequencies through the 100-volt range. Higher voltage ranges have two or more resistors and adjustable inner shields to control capacitive reactances. The resistance errors for these ranges cannot be calculated.

The TVCs were designed so that adjacent ranges could be compared. In a comparison their nearly identical 5-mA TEs are each first compared with one of the reference group of TEs. The proper resistor is then connected in series with one of the voltage converter TE's, TE_a , to make a 1-volt TVC. This is then connected in parallel with the other TE, TE_b , and compared at 0.5 volt. A 2-volt TVC is then formed with the next resistor and TE_b , which is then compared with the 1-volt TVC at 1 volt. TE_a is then connected with the next resistor to form a 3-volt TVC that is compared with the 2-volt TVC at 2 volts. This process is

continued until the highest range is reached (500V), and the relative ac-dc differences of all ranges are known. Ac-dc difference corrections are then assigned to each range based on the midrange converters (5 to 50 volts) where both the series resistors and the TEs can be evaluated theoretically and also experimentally in the inter-comparison tests. The technique as described has been used for over 3 years to make measurements and has shown no significant systematic errors.

¹ For further details, see *Thermal converters for audiofrequency voltage measurements of high accuracy*, by F. L. Hermach and E. S. Williams, IEEE Trans. Instr. Meas. IM-15, 260-268 (Dec. 1966).

² A thermoelement consists of a wire heater and a thermocouple. The hot junction of the thermocouple is fastened to the midpoint of the heater, and is electrically insulated from it with a small bead. The thermocouple emf is a measure of the current through the heater.

BUILDING SYSTEMS SECTION FORMED

■ The Administration's efforts to provide more favorable cost effectiveness in spending taxpayer's money are reflected in a new Building Systems Section which the NBS Institute for Applied Technology has started. The Institute includes the Building Research Division, headed by A. Allan Bates, where the new section is located. Chief of the Section is Robert W. Blake.

Currently the Section has underway a building systems development project to encourage more effective use of the Federal dollar expenditure for office-type space in the construction program of the Public Buildings Service (PBS) of the General Services Administration. PBS is funding the project and the work is a joint staff effort of the two agencies. Primary emphasis in this project is on formulating performance criteria—rather than product specifications—for the products, systems, or services purchased under the Government's office-space program. Industry will be invited to develop new design and construction solutions for the required performance.

The project mission includes these basic components:

- (1) To establish the needs of Federal office-space users and to relate these needs in a systematic way as *performance requirements* for the facility or building;
- (2) to use the performance requirements as a base to determine the *performance specifications* desired of the hardware components "or aggregates of components" of the building;
- (3) to direct proposals to building industry manufacturers for the development of products or systems to meet the performance specifications;
- (4) to develop methods to test and evaluate the industry products so developed against the Government performance requirements and specifications for its program;

(5) within the technical and management regulations in effect, to arrange to procure the new products which are responsive to the performance standards developed.

By June 1967, the systems analysis is to be completed and performance specifications with recommendations for action will be submitted to PBS for approval.

Close cooperation with industry will be a prime factor in the success of the project. A number of key questions will be examined in concert with industry. These include:

- What segments of the building products industry have a research and development capability appropriate to the product?
- What are the general and specific requirements for manufacturer involvement in the program?
- What groupings of manufacturers might be possible for systems component development in response to the Federal need?
- What specific information must be given to a manufacturer for him to participate?

The Section also is embarking on a series of studies of the methodologies employed in developing weapons systems from ideas to operation. The key elements of such processes will be analyzed to see how they might be transferred to the building process. This work is part of a broader approach to the problem of technology transfer and the stimulation of innovation and new application of technology, one of the missions of the NBS Institute for Applied Technology.

It is anticipated that the Building Systems Section will do work similar to the PBS project for other Federal agencies. For example, Mr. Blake, the chief of the section, has represented the Institute in discussions related to defining the requirements for Post Office Department facilities.



STANDARDS AND CALIBRATION

CALIBRATION SERVICE NOW AVAILABLE FOR COAXIAL BOLOMETER UNITS FITTED WITH 14-MM PRECISION CONNECTORS

The NBS Radio Standards Laboratory (Boulder, Colo.) announces a calibration service for the measurement of effective efficiency¹ of coaxial bolometer units fitted with 14-mm precision connectors² over a continuous frequency range from 4 to 8.5 GHz.³ Use of 14-mm precision coaxial connectors permits greater accuracy of measurement at radio frequencies than with the older Type N connectors. At present the calibration service is available for measurement at a nominal power of 10 milliwatts and for bolometer units fitted with thermistor-type elements having a nominal operating resistance of 200 ohms.

The calibration of coaxial bolometer units in the frequency range of 4 to 8.5 GHz is based upon a technique developed by Glenn F. Engen⁴ of the Radio Standards Engineering Division. The technique provides a means of transferring the calibrations of bolometer units in rectangular waveguide systems to coaxial bolometer units. This is accomplished with the aid of a coaxial-to-waveguide transition. Although a transfer is made from one type of transmission line to another, the uncertainty in measurement of effective efficiency of the coaxial unit is reasonably small.

In the frequency range of 4 to 7.05 GHz, the limits of uncertainty are ± 1.5 percent. In the frequency range of 7.05 to 8.5 GHz, the limits of uncertainty are ± 1 percent. These limits of uncertainties represent a 0.5 percent improvement over those obtained with Type N connectors. Because of resonance effects at higher frequencies in presently available 14-mm connectors, no calibration service is provided above 8.5 GHz.

¹ The effective efficiency of a bolometer unit is the ratio of substituted d-c power in the unit to the rf power dissipated within the bolometer unit.

² "Precision Coaxial Connectors," Recommendations of the IEEE I-M Group Subcommittee on Precision Coaxial Connectors, Revised July 10, 1966. This report describes the mechanical, electrical, and environmental requirements for precision coaxial connectors. It is available on request from: Secretary, IEEE-G-IM Technical Committee on High Frequency Instruments and Measurements, Section 252.32, NBS Radio Standards Laboratory, Boulder, Colo. 80302.

³ Sections 201.912a-2 and 201.912a-21, Title 15, Code of Federal Regulations. The text of these schedules appears in Insert 8, one of a series of supplements to NBS Misc. Publ. 250, Calibration and Test Services of the National Bureau of Standards, 1965 Edition. The Inserts are sent without charge to holders of Misc. Publ. 250 who have asked to be put on the mailing list for them. Misc. Publ. 250, 1965 Edition, is available at \$1 per copy from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

⁴ Coaxial power meter calibration using a waveguide standard, by Glenn F. Engen, J. Res. NBS 70C (Engr. and Instr.), 127 (Apr.-June 1966).

STANDARD FREQUENCY AND TIME BROADCASTS

WWV—2.5, 5.0, 10.0, 15.0, 20.0, and 25.0 MHz

WWVH—2.5, 5.0, 10.0, and 15.0 MHz

WWVB—60 kHz

Radio stations WWV (Fort Collins, Colo.) and WWVH (Maui, Hawaii) broadcast signals that are kept in close agreement with the UT2 scale by making step adjustments of 100 ms as necessary. Each pulse indicates that the earth has rotated approximately 15 arcseconds about its axis since the previous one. Adjustments are made at 0000 UT on the first day of a month. *There will be no adjustment made on August 1, 1967.* The pulses occur at intervals that are longer than 1 second by 300 parts in 10^{10} due to an offset in carrier frequency coordinated by the Bureau International de l'Heure (BIH), Paris, France.

Radio station WWVB (Fort Collins, Colo.) broadcasts seconds pulses derived from the NBS Time Standard (NBS-III) with no offset. Step adjustments of 200 ms are made at 0000 UT on the first day of a month when necessary. BIH announces when such adjustments should be made in the scale to maintain the seconds pulses within about 100 ms of UT2. *There will be no adjustment made on August 1, 1967.*

WWVB COORDINATED WITH DCF77

According to present information, the only two standard time stations directly broadcasting the internationally recognized unit of time (the atomic second) according to a coordinated system are the National Bureau of Standards station WWVB, at Fort Collins, Colo., and station DCF77, at Mainflingen, West Germany, associated with the Physikalisch-Technische Bundesanstalt in Braunschweig, and operated by the West German Post Office. Both stations use the Stepped Atomic Time System in which the time pulses are 1 atomic second apart and the carrier frequencies remain constant at their nominal values.

However, their signals also provide an approximation to Universal Time (UT) for use (among other purposes) in earth navigation. UT is a slightly variable time scale since it is adjusted to be in synchronization with the earth's rotation. The approximation to UT is achieved by occasionally making 0.2-second clock retardations or advancements in the epoch of the pulses. This is done as needed to maintain the approximation of UT within about 100 ms, and the changes are announced in advance. As a result, the time broadcast by these stations differs from the *uniform*

atomic time scale by varying integral multiples of two-tenths of a second—for the present, beginning 1 March, the difference is 5.6 seconds.

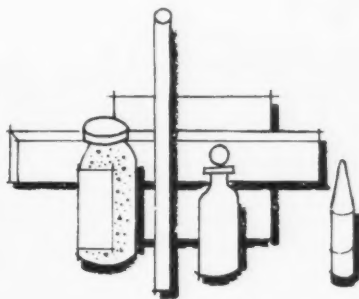
The two stations, by working through the Bureau International de l'Heure (BIH),¹ are now coordinated; that is, their time pulses are now synchronized to within 1 millisecond. To preserve coordination, they will hereafter make all step adjustments simultaneously. The last step adjustment of 200 ms announced by the BIH was to be effected on 1 June 1967.

The broadcasts from other stations, including the other

NBS stations, employ a system based in part upon carrier frequencies that are offset by 300 parts in 10^{10} below their nominal values. This necessitates that occasional adjustments be made both in the offset and in the clock reading in order to approximate UT.

¹ The Bureau International de l'Heure, situated at the Paris Observatory, was founded to coordinate the practices followed by the national times services in observations and calculations for the determination of time, and to establish precise international standards. It functions under the auspices of the International Astronomical Union, the International Union of Geophysics and Geodesy, and the International Scientific Radio Union.

STANDARD REFERENCE MATERIALS



The Office of Standard Reference Materials has recently prepared and certified new standard reference materials for oxygen in steel and oxygen in titanium alloys, and a butyl rubber Mooney viscosity standard. It has also issued renewals of plutonium and butyl rubber standards.

Developed to meet the critical needs of science and industry in research, production control, and customer acceptance evaluations, these standards will be used for calibrating measurement equipment or measurement systems in the purchasers' laboratories. The new standards have been added to the more than 600 other standard materials¹ sold by the Bureau for use in calibrating spectrometers, temperature measuring equipment, viscometers, and other apparatus used to measure or determine radioactivity, isotope ratios of elements, dielectric properties, particle size, or the constituents of chemical compounds and metal alloys.

OXYGEN IN METALS

Five new standard reference materials have been certified for oxygen content by the Bureau and 19 cooperating laboratories. Three of these are steel standards and the others are titanium-base standards. The steels are NBS Standard Nos. 1090, ingot iron; 1091, stainless steel (AISI Type 431); and 1092, vacuum-melted steel. The two titanium-base standards are NBS Nos. 355, titanium, and 356, a 6 aluminum, 4 vanadium alloy. All five of these

standards provide materials of known oxygen content and homogeneity intended primarily for calibrating vacuum fusion or inert gas fusion equipment, used in correlating the oxygen content of metals with fabricating and performance characteristics. Oxygen is recognized to react with constituents of alloys to form solid, brittle inclusions. These cannot be tolerated in metals for such critical applications as in aircraft landing gear, pressure vessels for nuclear reactors, components of space vehicles, drill pipe for deep oil wells, or in piping for high pressure lines.

Each of these standards costs \$20 per unit and is in the form of rods. NBS Nos. 1090 and 1092 are one-fourth inch in diameter and 4 inches long; No. 1091 is five-sixteenths inch in diameter and 4 inches long; and Nos. 355 and 356 are one-half inch in diameter and 2 inches long.

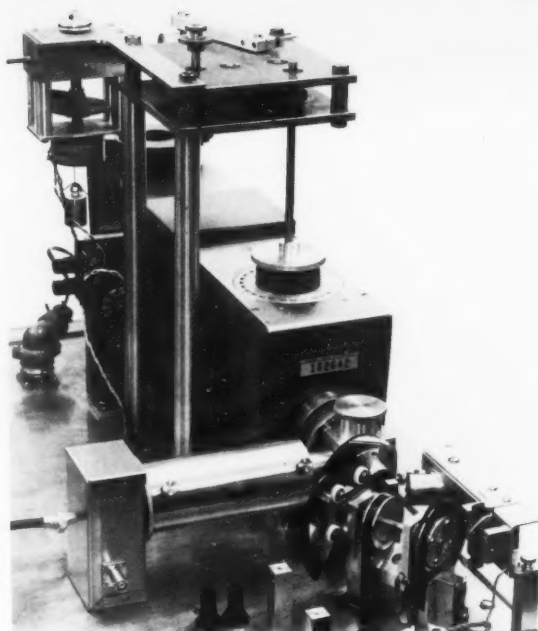
RUBBER STANDARDS

Both a new and renewal standard of butyl rubber, IR Type 218, have recently been certified. The new standard, NBS No. 390, has been selected for use as a Mooney viscosity standard. The other, NBS No. 388d, replaced NBS No. 388c, the supply of which has been exhausted. Both of these standards were evaluated by G. E. Decker, G. W. Bullman, and A. M. Brown of the Materials Evaluation Laboratory of the NBS Institute for Materials Research (now in the Institute of Applied Technology). These standards are vital to process control of synthetic

continued on page 136

Photodetector response is calibrated by a machine which measures detector output under monochromatic light swept across part of the electromagnetic spectrum.

Some light from the monochromator (shoebox-shaped unit) is directed by a beamsplitter to the detector under test; the remainder goes to a mechanical-optical-electrical system which stabilizes the monochromatic energy.



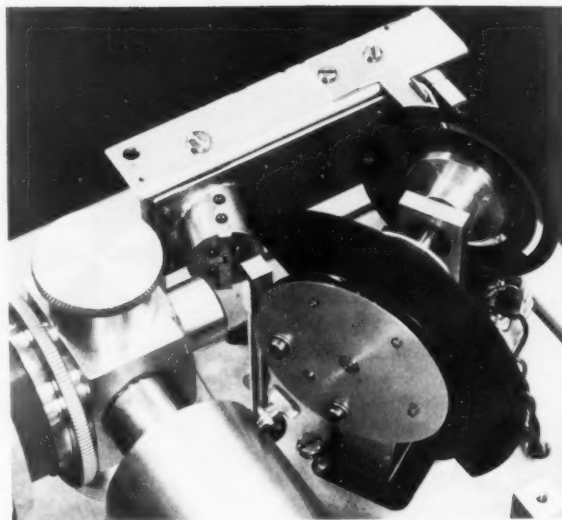
RAPID CALIBRATION OF PHOTODETECTOR RESPONSE

Device Scans Visible Wavelengths

■ In recent years photosensitive electrical devices have become increasingly diversified and of growing importance in our space-age technology. None of the devices are uniformly sensitive to all colors and the response of many extends beyond the visible portion of the spectrum; their characteristics must be known in order to select the right type for any application.

The National Bureau of Standards has recognized this need and its electronic-optical development laboratory has developed an instrument which calibrates photodetectors in the visible spectrum, from violet to red (0.38 to $0.8 \mu\text{m}$). Designed by Milton L. Kuder to specifications and along lines set by Harry K. Hammond III of the Metrology Division, the instrument enables the Bureau to produce photodetector response curves in only minutes instead of hours. This capability is now regularly used by, among others, the National Aeronautics and Space Administration in selecting photodetectors for identifying stars by wavelength and for holding bearings for satellite and spaceship guidance.

The new calibrator-recorder illuminates the photodetector under test with light from a monochromator swept across the desired portion of the visible spectrum and records the output as a function of wavelength. Its circuitry holds the illuminating energy at a fixed level to



Closeup of optical paths of photodetector calibrator.

make possible measurement precisions of 2 percent. The instrument automatically scans and records photodetector response all the way across the visible spectrum in about 4 minutes, making it especially well adapted for calibrating large numbers of photodevices with moderate accuracy.

Photodetection

Photodetectors in use today are of several types: The

photoemissive (photodiodes and photomultipliers), the photovoltaic (such as the selenium cell, which generates voltage), and the photoresistive (such as the cadmium sulfide cell, which varies in resistance). Although spectral response is not critical in some applications (such as security and motion picture sound systems), it must be known for increasingly numerous applications, such as the NASA starseeker, color exposure meters, and scientific instruments.

In the past the spectral response of photosensitive devices has been determined by measuring device output at selected wavelengths of monochromatic illumination at constant energy, using a calibrated thermopile as an intensity reference. A series of values obtained by this method is used to plot a curve showing response.

Although the reference thermopiles used have essentially flat spectral responses, they are extremely sensitive to ambient temperature. The spectral calibrator developed at the Bureau is freed of temperature instabilities and resulting inaccuracies by use of a constant light source as a reference and the thermopile as an intensity difference-sensing device. It compares the reference and monochromator output 13 times a second, using a light-chopping method, to eliminate thermal drift and to stabilize monochromator output.

Automatic Calibrator-Recorder

The automatic calibrator-recorder consists basically of a single-grating monochromator, the light from which is split into one path leading to the photoelectric specimen under test and the other to a sensitive thermopile. Cutaway portions of a spinning mirror admit light to the thermopile alternately from the monochromator and a small incandescent lamp energized by a regulated power supply. The spinning mirror allows the thermopile to sample the monochromator and the reference illumination alternately; the a-c difference signal from the thermopile is amplified to electronically control the current supply to the monochromator incandescent bulb for a null difference signal.

The calibrator is used by mounting the photoelectric device under test to receive its part (8 percent) of the monochromator beam, setting the monochromator to the shortest wavelength possible, and setting the reference light source to the greatest output (for best signal-to-"noise" ratio) at which the null can be obtained. The X-Y plotter (the curve recorder) and the drive slowly advancing the monochromator wavelength are then placed in operation. A precision potentiometer turning with the wavelength selector controls the X coordinate of the plotter, while the amplified output of the specimen photodetector controls the Y coordinate. The normal scan is completed in about 4 minutes, but it can also be reversed to obtain plots made in both directions in order to identify and measure hysteresis effects. The accuracy obtained by this machine

has been found to be within 4 percent over the entire visible spectrum.

The thermopile used to sense the monochromator-reference difference has a jet black receiver area of 2 x 6 mm in a vacuum behind a quartz window. It has a time constant of 40 msec, an output impedance of approximately 10 ohms, and a sensitivity of approximately 8 μ V per μ W. It is transformer-coupled to a high-gain amplifier, the output of which operates a duty cycle-modulated, 500-Hz source of voltage to the monochromator light. The constancy of the monochromator energy output is referred to the reference by the servobalance and stabilized with an accuracy within about $\pm 1/2$ percent.

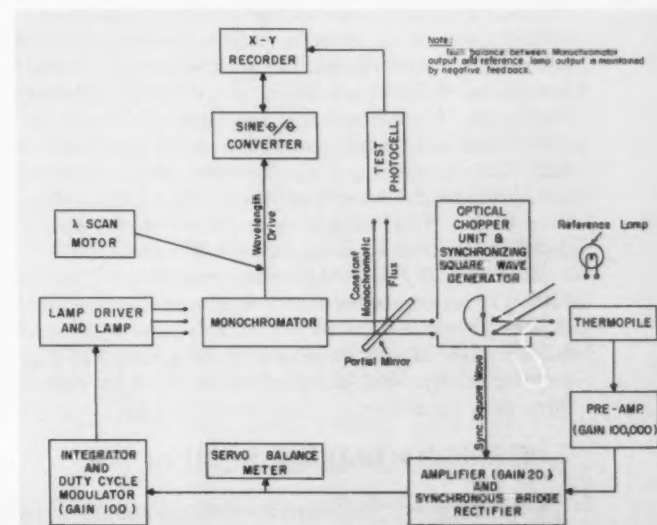
Test Conditions

The output of a photomultiplier or photoresistive specimen is supplied to the ordinate input of the X-Y recorder via a temperature-compensated cathode follower or an operational amplifier. The electrical conditions specified for photomultipliers are: cathode to first dynode: 150 V; last dynode to anode: 100 V; intermediate dynode voltages set for a 20-V input to the recorder; anode-load resistance: 10 megohms; and maximum anode current: 2 μ A.

Photodiodes and photoresistive photocells are measured in series with a constant-voltage source of 10 V, using a 10-megohm load resistance. The output is applied to the

continued

NBS photodetector response recorder exposes test photodevice to monochromatic light scanned across the visible spectrum. The thermopile samples alternatively light from the monochromator and from a reference lamp of fixed intensity; much of the circuitry is concerned with setting the monochromator output power to equal that of the reference.



RESPONSE *continued*

recorder via the cathode follower or operational amplifier.

Photovoltaic cells are tested under virtual short-circuit conditions (as prescribed) by connecting them to drive an operational amplifier which limits the potential across the cell to $2\ \mu\text{V}$ or less during measurements.

The overall servobalance system produces a wavelength lag error as small as $0.001\ \mu\text{m}$ on the wavelength scale. For this reason the direction of the scan is manually indicated on the graph when a single scan is made. The hysteresis effect can be appraised and compensated for if the response is scanned in both directions.

Present Photometry Research

The machine described is a specialized one, intended for running fast plots of photocell response for varied wavelength where 4-percent accuracy is acceptable. The staff of the Bureau's photometry laboratories is now engaged in the development of an equally specialized photoreponse instrument. Yielding values for a succession of wavelengths from which points of the response curve can be plotted, it is expected to have an accuracy within 1 percent, but with an increased running time.

David Goebel plugs a photoelectric cell into an instrument for calibrating spectral response.



REFERENCE MATERIALS *continued*

rubber used in the annual production of more than 50 million tires for the Nation's automobiles.

NBS No. 390 was prepared from a single slurry tank of crumb. As the lot was selected, 1,000-gram samples were removed at intervals and two determinations of Mooney viscosity were made on each sample according to ASTM test designation D1646-63. The certified value of viscosity for the lot is 74.5 ± 1.5 ML 1+8 ($100\ ^\circ\text{C}$). (The ML 1+8 ($100\ ^\circ\text{C}$) indicates that the Mooney viscosity was determined using a large rotor; the rubber was heated at $100\ ^\circ\text{C}$ for 1 minute prior to operation of the rotor and was sheared for 8 minutes at $100\ ^\circ\text{C}$ before the readings were made.) This standard with the accompanying certificate is available in 27-kg units for \$95.

NBS No. 388d is sold in units weighing 27 kg for \$105. The accompanying certificate gives values for stress at 400 percent elongation and at failure, elongation at failure, strain at $400\ \text{lb/in}^2$ and at $5\ \text{kg/cm}^2$, and electrical resistivity. Most of the values are given for each of three cure conditions.

PLUTONIUM METAL

A renewal of NBS Standard No. 949b, plutonium metal with an atomic weight of 239.07, has been issued to pro-

vide a reference standard for the chemical assay of plutonium. Accurate assay for this element is very important to the rapidly expanding nuclear industry for inventory control of fissionable material and in many of the Nation's research activities related to applications of nuclear energy. This material was prepared and analyzed by the Los Alamos Scientific Laboratory of the University of California, Los Alamos, N. Mex., in collaboration with the Bureau; the plutonium assays at 99.99 ± 0.08 percent.

The americium from decay of the 14-year plutonium was approximately 10 ppm at the date of issue, and will increase less than 20 ppm per year. The total of other detected impurities is less than 100 ppm. Repeated determinations for impurities indicate that the metal is quite homogeneous.

Each standard consists of two or three pieces of the metal sealed in a glass tube under a reduced-pressure argon atmosphere. The number of metal pieces and their weights are given on each tube. NBS No. 949b is sold with a certificate for \$88 per unit and weighs approximately 0.5 gram.

¹ For a complete list of NBS standard materials, see Standard Reference Materials: Catalog and Price List of Standard Materials Issued by the National Bureau of Standards, NBS Misc. Publ. 260, for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for 45 cents.

CONFERENCE & PUBLICATION *Briefs*

INDUSTRIAL RESEARCH INSTITUTE VISITS BUREAU

A special meeting of the Industrial Research Institute (IRI) was held April 10 and 11 so that representatives of its member companies could learn about the current programs and facilities of the National Bureau of Standards. The meeting took place at the Bureau's new facilities in Gaithersburg, Md., and consisted of a series of briefings on NBS research, visits to NBS laboratories, and a description of activities by the Congress and the Executive Branch to increase the effectiveness of the Nation's scientific effort.

The meeting brought together about 200 research directors and scientists from over 100 companies conducting privately financed research. IRI's member companies represent the major fraction of the industrial research effort carried out in the United States.

The attendees were welcomed to the Bureau by NBS Director A. V. Astin who explained the role of NBS by giving a glimpse of the Bureau's resources, programs, and outputs. He emphasized the need for increased communication between industry and NBS. Dr. Astin was followed by senior Bureau staff members who gave brief descriptions of the services NBS makes available to industry. These services include: standard reference materials, standard reference data, engineering standards, calibration and measurements, and dissemination of technical information.

The afternoon session started with a briefing on the Bureau's Research Associate Program which is a cooperative effort in research between NBS and industry. The program makes it possible for scientists and engineers sponsored by individual companies, such as members of IRI, to conduct research at NBS. Research Associates now at NBS from IBM, American Cyanamid, Procter & Gamble, and Dow Chemical told about their current work. Presentations followed on NBS activities in polymers research, analytical chemistry, inorganic materials research, metallurgy, building technology, precision thermodynamic measurements, reference data and NBS data centers, and measurement standards.

In the evening, Congressman Emilio Q. Daddario, Chairman of the Subcommittee on Science, Research, and Development of the House Committee on Science and Astronautics, spoke of congressional cooperation with the scientific and technological communities "to make

what is possible scientifically, attainable politically."

The next morning, participants attended lectures on specialized Bureau competences and toured four major NBS laboratories. The lectures dealt with computer-assisted research, laboratory automation, surface chemistry research, corrosion, electron impact spectroscopy, electron probe microanalysis, electrodeposition of metals, crystal growth, and activities of the Clearinghouse for Federal Scientific and Technical Information. The four laboratories visited were the Bureau's high-flux reactor, the 100-MeV linear accelerator, the engineering mechanics building with its 12-million-lbf capacity hydraulic testing machine, and the environmental engineering laboratories used for building research.

At the luncheon on April 11, Donald W. Collier, president of IRI, commented on the value of the direct contacts between industry and NBS that were so successfully expanded by this meeting. He also said that there is "a growing need and interest by IRI members to contribute their backgrounds and experience more effectively in aiding government and the universities in formulating their research policies and programs."

At the same luncheon, Acting Under Secretary of Commerce J. Herbert Hollomon reviewed the 4-year record of the Commerce Technical Advisory Board (CTAB) and gave highlights of studies by its panels and committees on engineering and commodity standards, the patent system, transportation research and development, surface-effect ships for ocean commerce, telecommunications science, invention and innovation, and high-speed ground transportation. Studies in progress, he said, are concerned with science and technology for the development of industry and commerce, and future automotive power sources, particularly as they have significance for the air pollution problem.

The afternoon session provided an opportunity for participants to attend a meeting of the Commerce Technical Advisory Board where some of its panel reports were discussed in more detail. Concurrently, about 75 of the Bureau's laboratories were open to the IRI visitors for detailed exploration and personal discussions about the work being performed.

NBS HOSTS AUTOMOTIVE ENGINEERS

The Seventh Annual Armed Forces Industry Meeting of Automotive Engineers was held April 18, 1967, at the

continued

BRIEFS *continued*

NBS facilities at Gaithersburg, Md. SAE's Baltimore, Washington, and Virginia Sections sponsored the meeting and over 100 members attended. A. V. Astin, NBS Director, welcomed the visitors to the Bureau.

The program chairman was J. C. Fielding of Roylyn, Inc. The program included automotive safety, the National Measurement System, and metal fatigue.

Speaking on "The National Measurement System" (NMS) R. D. Huntoon, Director of the NBS Institute for Basic Standards, described it as a systems approach that provides a logical, systematic way of looking at the measurement activities in this country. The NMS now represents an investment, he estimates, of about \$50 billion, largely for instrumentation and data-producing research and is on an activity level comparable with other important national systems such as communication and transportation.

During the morning session P. J. Brown, Program Manager of the NBS Office of Vehicle Systems Research, covered the role of NBS in motor vehicle safety research. Mr. Brown explained the relationship between the National Traffic Safety Bureau and NBS in the motor vehicle safety program. He outlined in detail three areas of research—tire systems, braking systems, and occupant restraint systems—which NBS will investigate in order to make recommendations to NTSB for standards of automotive safety.

In the research for tire safety standards, laboratory and field tests will be employed. To develop a uniform quality grading system, test methods will be developed to measure tire characteristics, such as thread life, carcass strength, traction capabilities and cornering behavior.

Braking systems will be investigated from the brake fluid to the entire integrated braking system. Here again laboratory and field tests will be conducted to provide the maximum of data.

The third system, occupant restraint, will involve the dynamic simulation of collisions. A new dynamic testing device has been designed and built by NBS and is now being fully instrumented. Under the Bureau's sponsorship, the facilities of Holloman Air Force Base are conducting sled tests using anthropomorphic dummies, animals, and human volunteers to test occupant restraint systems.

A talk on metal fatigue was given by John Bennett of the NBS Institute for Materials Research. He discussed the role imperfections in metals play in fatigue behavior and in the useful life of the metal.

R. H. Isbrandt, national president of SAE and vice-president of American Motors Corp., spoke at the members' dinner meeting. He emphasized SAE's voluntary standards-making activity over the years and its excellent reputation as a "good partner" in promoting the technical advancement of this country. Mr. Isbrandt reiterated the need for sound engineering standards and cited the need for greater cooperation by all standards-making organizations. He urged a concerted effort to make the public fully

aware of the great potential that these standards hold for human progress and pledged the support of the Society of Automotive Engineers in such an endeavor.

During the afternoon a tour of NBS facilities was conducted for the Society's members. The tour included visits to laboratories engaged in the following activities: Laser studies, environmental engineering, fire research, engineering metrology, vibration testing, force measurement, metallurgy, field emission microscopy, and gear measurement. NBS staff members were on hand to give explanations and to answer questions.

AMERICAN ORDNANCE ASSOCIATION MEETS AT GAITHERSBURG

The Standards and Metrology Division of the American Ordnance Association held its 22d annual meeting April 12 and 13 at the National Bureau of Standards' Gaithersburg (Md.) laboratories. The theme for the meeting was "The National Measurement System."

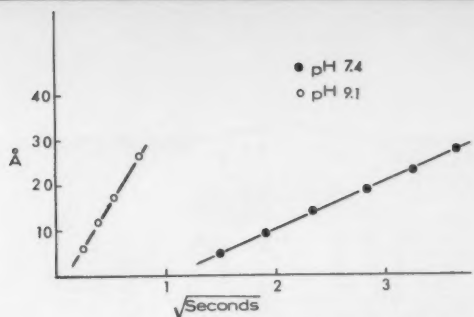
In the keynote address, R. D. Huntoon, Director, NBS Institute for Basic Standards, pointed out that the National Measurement System provides a quantitative measurement basis for interchangeability and decisions for action—in public affairs, in commerce and industry, and in science and technology. He described the System as yielding consistent instrumentation, evaluated reference data, and criteria for meaningful measurement.

Following the keynote address, E. A. Mechtly, Department of Electrical Engineering, University of Illinois, gave a talk on the use of the International System of Units (Système International d'Unités) at the National Aeronautics and Space Administration. S. J. Lorber, Acting Chief, Quality Control, U.S. Army Materiel Command, then spoke on the management of quality and reliability in the Department of Defense. He was followed by I. C. Williams, Deputy Director, Southern California Center, World Trade Authority, who recounted the efforts of California to establish a legal qualification for professional metrologists. J. A. Swint, Operations Manager, Ford Motor Co., concluded the morning session, speaking on the quality control program for a transport vehicle recently developed for the Army.

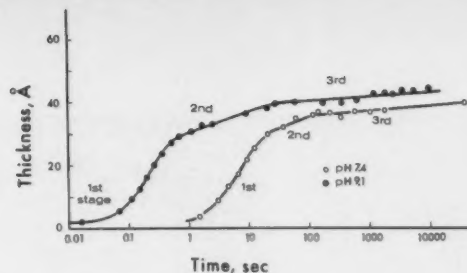
Speaking to the members at lunch, C. W. Sherwin, Deputy Assistant Secretary for Science and Technology, U.S. Department of Commerce, noted the current trend toward justification of scientific work by its economic effects. In the afternoon session J. R. Van de Houten, Supervisor, Measurement Standards Section, Aerojet-General Corp., gave a talk on a study by the National Conference of Standards Laboratories dealing with a typical standards laboratory in industry—its inputs, its outputs, and the interface factors affecting them.

At a banquet held the evening of the 12th, Maj. Gen. R. G. Ruegg, Assistant Deputy Chief of Staff, Systems and Logistics, U.S. Air Force, spoke on possible ways of im-

continued on page 140



These plots show film thickness versus time during the first stage of film growth.



These plots of film thickness versus time show three distinct stages of oxide film growth on iron.

ELLIPSOMETRIC-POTENTIOSTATIC STUDY OF IRON PASSIVITY

Corrosion is one of the greatest problems of modern industry. Oil and gas companies, the military services, and the transportation industry are but a few of the large users of metal that spend billions of dollars annually for maintenance and replacement of corroded equipment.

For many years the Bureau has been engaged in corrosion research. An important area of this research has been the investigation of iron passivity (formation of a protective film on a metal). Recently, J. Kruger and J. P. Calvert of the NBS Institute for Materials Research developed a technique¹ for study of iron passivity film growth for the first few tenths of a second after growth initiation. It is hoped that such studies will ultimately lead to improved maintenance methods for preventing or reducing corrosion.

Previous investigations² have been performed in the area of iron passivity. This study, however, extends and complements these investigations in several ways. In this investigation, for example, film growth was studied using the optical technique of ellipsometry that allows a direct nonelectrochemical method of measuring film thickness. In film thickness determination, this method eliminates any other possible current-producing reactions not involved in film formation. In addition, it was possible to study the kinetics of film formation in the early stages (first few tenths of a second). Also, the electrolyte was chosen so that little oxide film dissolution occurred. This is important because it prevents surface roughening that complicates the interpretation of ellipsometric measurements.

In this study, an iron specimen was mounted in a holder and inserted into a cell containing a sodium borate-boric acid solution. A potentiostat was used to hold the iron specimen at the voltage required for a passive film formation. Using an ellipsometer, the investigators were able to study film growth by the change in the optical parameters

of the metal surface caused by changing film thickness.

The ellipsometric measurements have shown three separate stages in the film formation. In the first stage, film thickness was plotted as a function of the square root of time, showing a linear relationship. The slope of the line was greatest for the line representing growth in the solution with the highest pH factor. This indicates that the solution, rather than any property of the film itself, is controlling growth.

In the second stage there is a departure from the linear relationship between thickness and the square root of time. When this occurs the solution is no longer the rate-controlling factor, and there is a change in the type of rate law governing the process. This stage appears to be a transition period between the solution-limited growth of the first stage and the steady-state film-limited growth of the third stage.

The third growth stage is characterized by a steady growth rate and occurs after about the first minute of the growth process. This stage fits equally well a logarithmic or an inverse logarithmic rate law.

A few experiments were carried out using two metal single crystal surfaces of (110) and (311) orientations. Plots of film thickness versus time on these surfaces show that orientation of the metal surface also affects the rate of film growth. The (110) surface (closest packed surface) exhibited the higher growth rate.

The iron specimens used were refined by a floating zone technique. They had less than 10 parts per million gaseous impurities and less than 130 ppm metallic impurities.

The iron specimens were washed, polished, and then dried in a jet of pure oxygen before being placed in the cell. Once the specimen was placed in the cell and deaerated solution was admitted, it was possible, before growing a film, to reduce any existing oxide film on the iron surface by polarizing the surface galvanostatically to a cathodic

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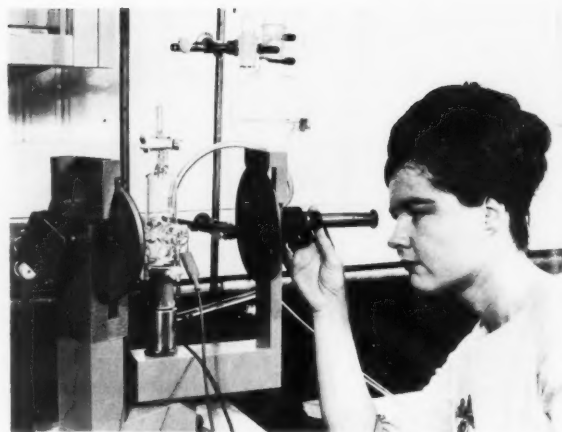
IRON PASSIVITY *continued*

potential. After cathodically reducing the iron surface, the solution was completely replaced by fresh solution with the metal surface maintained at the reduction potential. When the specimen was so reduced, optical readings were made and the surface then brought rapidly to the anodic potential where films start to form. Film formation was carried out in the potential region $-0.4V$ to $+0.8V$. Experiments were made at room temperature ($25 \pm 1^\circ C$).

After the surface was cleaned, the ellipsometer was set at its extinction point (a minimum of light impinging on the photomultiplier tube). A fast two-channel recorder was connected to the photomultiplier tube to record the photocurrent along with the electrochemical current or potential. As soon as the film formed on the metal, the ellipsometer was no longer at the extinction point and the intensity of the light reaching the photomultiplier tube increased. For films less than 50 \AA this light intensity was approximately a linear measure of the amount of film formed.

¹ For further information, see Ellipsometric-potentiostatic studies of iron passivity. I. Anodic film growth in slightly basic solutions, by J. Kruger and J. P. Calvert, *J. Electrochem. Soc.* **114**, 43 (1967).

² M. Nagayama and M. Cohen, *J. Electrochem. Soc.* **109**, 981 (1962). See also N. Sato and M. Cohen, *J. Electrochem. Soc.* **111**, 512 (1964).



Joan P. Calvert obtains ellipsometric readings during an investigation of the formation of a corrosion-protective film on iron.

BRIEFS *continued*

proving the reliability of the increasingly complex equipment needed by the Air Force, such as the Minuteman guidance system. He said that in 7 years Air Force calibrations have required not only an order-of-magnitude increase in precision and accuracy, but entirely new standards for such items as infrared radiation, lasers, and microwave power.

The three sections of the AOA Standards and Metrology Division held workshops the following morning. The Dimensional Standards Section discussed papers on surface texture, ultrafine finishes, positioning by lasers, and texture as an influence on length interferometry. The Electrical and Electronic Standards Section heard a description of the new metrology laboratory at Redstone Arsenal, and an account of the services offered by NBS. The General Physical Standards Section discussed aerospace applications of fluid flow measurement, error sources in azimuth determination, and techniques of using standard reference materials to measure thermal expansion.

The final part of the meeting included a tour of selected laboratories. The members were shown applications of spectrophotometry, thermometry, gear measurements, surface finishing, electrical standards for voltage and capacitance, and the pilot program for mass measurements.

THE STRESS CORROSION OF METALS

The Stress Corrosion of Metals, by NBS physicist Hugh L. Logan, is the first volume in English in which a single author has brought together previously published material on this subject. In 306 pages, the work covers a broad study of stress corrosion phenomena in alloy systems and correlates the information with today's theories on the mechanism of stress corrosion cracking. The volume was prepared by Mr. Logan at the request of the Electrochemical Society as one of the Society's Corrosion Monograph Series.

Separate chapters deal with stress corrosion cracking in low carbon steels, high strength steels for aerospace, various stainless steels, and copper, aluminum, nickel, magnesium, titanium, and miscellaneous precious metal alloys. In each chapter, techniques are discussed for eliminating stress corrosion. Methods of identifying failures as well as analyzing the failures are set forth in an additional chapter. The final feature of the book provides methods of evaluating the resistance of metals to stress corrosion.

The Stress Corrosion of Metals (\$13.95, John Wiley & Sons, Inc., New York, 1966) can be considered an important contribution toward the growth of knowledge on stress corrosion cracking in high strength metals and alloys.



NEWS

This column regularly reports significant developments in the program of the National Standard Reference Data System. The NSRDS was established in 1963 by the President's Office of Science and Technology to make critically evaluated data in the physical sciences available to science and technology on a national basis. The System is administered and coordinated by the National Bureau of Standards through the NBS Office of Standard Reference Data, located in the Administration Building at the NBS Gaithersburg Laboratories.

Classification and Indexing at the Office of Standard Reference Data

Classification and Indexing proved to be the most controversial topic on the agenda of the Discussion Forum of the Operators of Data and Information Centers associated with the NBS Office of Standard Reference Data, which was held at the Bureau recently. Because of the great interest generated in the subject, some of the approaches and factors involved in classification and indexing will be reviewed in this and subsequent issues.

Classification and indexing of information and data are basic requirements for the efficient operation of an information service. One segment of such a service is its data file operation. The objective of this operation is to organize the collection of data and information by means of a classification and indexing system so as to provide ready and efficient retrieval of data and information to competently answer properly structured queries. Properly designed, a classification and indexing system can minimize the work involved in negative searches by readily identifying those subjects not within its collection. In this first review, it is therefore necessary to define classification and indexing.

Classification is a technique by which documents and information are "fitted" into a preestablished scheme. The essence of classification is to design the scheme so that the one most suitable class of items is placed into a group by virtue of its role within the scheme.

Indexing is a technique for locating and retrieving items from a collection. It may also be a device that, when triggered by an inquiry, identifies the subclass of items within a class of items that applies to the subject of the inquiry. An inquiry is a question directed to an informa-

tion system that requires the index to locate a particular item from the collection, if there is one, that satisfies the inquiry.

Conventional libraries rely on author and subject indexing as well as classification as a principal means of retrieval. The preparation of author indexes is straightforward; the design of subject indexes, however, can be very complex. There are two basic approaches: Single access indexing and coordinate or conjunctive indexing. The standard index found in the back of a book is typical of the single access approach. Such an index limits the method of searching to one term at a time. The coordinate index, on the other hand, permits searching for information that can be characterized by a number of terms in conjunction.

Consider, for example, the inquiry, "Give me information on the effect of gamma irradiation on the absorption spectrum of potassium permanganate solutions." In the single access index, the searcher will search one of the terms first (probably potassium permanganate). The index will locate all items that discuss potassium permanganate in any sense whatever. The searcher must screen these documents and discard those items not related to gamma irradiation effects on its absorption spectrum. Similar searches may have to be performed for the remaining important terms in the inquiry. Use of the coordinate index on the other hand, requires only one search; the searcher will look for all three terms, potassium permanganate, absorption spectrum, and gamma irradiation, in conjunction. A coordinate index locates only those items indexed by all three terms of the search, thus eliminating most of the manual screening inherent in single access indexes. There are various coordinate indexes in use today, and such approaches lend themselves to mechanization.

With a universe of about a million substances and more than a thousand properties, however, even the coordinate indexing approach faces a very formidable problem in the NSRDS indexing requirements.

In the present early stages of development and restricted resources the Office of Standard Reference Data can respond only in a limited way to inquiries. Its response is based on the contents of its data file or referrals to knowledgeable individuals at the Bureau or at associated data centers. Its data file comprises approximately 25

continued

NSRDS NEWS *continued*

NSRDS and related publications¹ and 800 worldwide physical property data compilations. Within the next year the number of NSRDS and related publications is expected to double and the number of other compilations to increase 50 percent.

The initial classification and indexing procedures used for the publications collected by the Office of Standard Reference Data are exploratory steps toward what is expected to be a large mechanized system. The difficulty in developing classification and indexing systems that withstand the test of file growth, time, and complexity is recognized. For this reason, the experimental nature of the present effort is emphasized. As no existing widely used classification scheme is satisfactory for NSRDS needs, it is necessary to develop a new scheme. The present small size of the file and its highly specialized nature and use are important factors that make it reasonable to devise a classification system suited to the particular needs of the Office of Standard Reference Data. The present approach is intended to do this and at the same time to maintain flexibility to change as the system changes.

Classifying publications to provide for a shelf location and for convenient browsing should be considered a somewhat different problem than that of indexing contents to permit rapid location of individual data points. A classification scheme for shelving does not need to have a large number of partitions of the subject matter. Factors that should not be ignored in deciding the number and size of the partitions are: the needs of the user, his familiarity with the shelving system, and his subjective reactions while browsing. For this reason, the approach to shelving holdings at the Office of Standard Reference Data emphasizes the needs of those who use the file for browsing—the professional staff of the Office. Eight classification categories are used:

1. General
2. Nuclear properties
3. Atomic and molecular properties
4. Solid state properties
5. Thermodynamics and transport properties
6. Chemical kinetics
7. Colloid and surface properties
8. Mechanical properties of materials.

This partitioning results in groups that contain at present an average of 150 items. Further subject breakdowns are being explored on the basis of utility to the user. At present it appears that more than one scheme of classification may be required. In particular, nuclear properties data cannot be subdivided on the basis of chemical substance classes like organic and inorganic, whereas the other categories subdivide fairly well on the basis of chemical substance. The present approach is to accept this difficulty as a fact and to institute a separate scheme for subdividing nuclear data—by dividing property data on

the basis of time-dependent and stationary states. Additional subdivisions of the file will be developed as the need arises with the increased file size.

The first and primary indexing task of the Office of Standard Reference Data is to develop reference terms to aid in locating specific data on the physical properties of well-defined substances. In a collection of approximately 800 compilations, it is not an arduous task, even without indexing aids, to locate data points when a specific property and substance are cited. However, as the number of inquiries increases, time-saving indexes should be of significant value, especially for inquiries where a list of properties by substance and/or a list of substances by a stated property value or set of values is desired.

The task of indexing in-depth (identifying each data point) a collection of 800 items that grows at the rate of 400 items per year would be an overly ambitious undertaking at this time. However, in-depth indexing of the NSRDS publication collection, which contains less than 25 items and which is now growing at the rate of 25 items per year, is feasible when considered as a pilot operation to determine more exactly the needs and capabilities of the Office. This approach should provide more information on the magnitude of the task, immediate assistance for responding to inquiries, and should indicate future directions for exploration as greater numbers of inquiries are handled. The proposed system will attempt to define a data point by physical property and substance terms.

Initial efforts to index the NSRDS data compilations indicate that in-depth indexing of properties and materials should be based on the following guidelines:

1. Subject matter knowledge is essential for adequate indexing.
 2. A single pass through a compilation is not sufficient to obtain all terms.
 3. An open-ended inventory of terms would be a useful aid to the indexing operation.
- These guidelines testify to the inherent difficulties of indexing even a limited and fairly well defined collection such as the one held by the Office of Standard Reference Data.

One of the first objectives will be to develop a method to identify rapidly those questions for which there is no answer in the file. Significant effort can be saved if at the outset file searches that will yield negative results can be identified. A thoroughly indexed collection of data points should provide this capability.

It may be meaningless to speak of an optimum indexing system as future demands on the system are undefined and, at present, cannot be known. Nevertheless, a well conceived and implemented indexing effort will be necessary to the successful operation of an inquiry service, particularly where the system is flexible and able to incorporate changes as the situation dictates. The Office of Standard Reference Data is hopeful that its approach to the indexing problem will yield a useful and flexible system.

CODATA Task Group on Computer Use

The Committee on Data for Science and Technology (CODATA) of the International Council of Scientific Unions has established a Task Group on Computer Use. This action is based on the following resolution, which was adopted by the Committee at its organizing meeting of June 16, 1966, in Paris:

It is recognized that in the generation, evaluation, storage, retrieval and dissemination of quantitative data, increasing use will be made of computers and other aids. Paralleling this development will be the need for the associated software to accomplish such tasks as coding, indexing, correlating, storing and transmission of numerical data. To assure the orderly development of the foregoing matters on a worldwide basis, it is recommended that the Committee establish a small Task Group composed of experts of the highest competence from different countries and disciplines to seek ways of achieving maximum exchange of information about the methodology of handling data, including software, and to stimulate new work in this field.

Franz L. Alt of the Office of Standard Reference Data has been named Chairman of the Task Group. In addition the following members have been appointed to date by Frederick Rossini, chairman of CODATA, acting on the recommendation of the national representatives on CODATA:

Arthur Armstrong, Atomic Weapons Establishment, Aldermaston, England
Gordon Black, Director, National Computer Center, Manchester, England
Jean d'Olier, Director-Adjoint, Documentation Center, CNRS, Paris, France
R. Fugmann, Department of Documentation, Farbwerke Hoechst, Frankfurt, Germany
R. Norman Jones, Division of Pure Chemistry, National Research Council, Ottawa, Canada
F. Schulte-Tigges, German Computation Center, Darmstadt, Germany

Mr. d'Olier invited the Task Group to hold its first meeting in Paris on June 8th. The following topics were included in the agenda of this meeting.

1. Organization of the Task Group
2. Liaison with other organizations
3. Reports from members on status of data automation in their countries
4. Plans for future activities.

Liaison will be maintained with the International Standards Organization and especially its Technical Committee for Computers and Data Processing (TC-97); with the European-American Nuclear Data Committee; with the International Computation Center of UNESCO in Rome; with the International Federation for Informa-

tion Processing; and with the International Federation for Documentation. It is expected that among the first activities of the Task Group will be the preparation of a report, or series of reports, on data automation in various countries.

New Russian Translation

The Alloy Data Center, of the NBS Alloy Physics Section, has recently had the *Handbook of Binary Metallic Systems*, by A. E. Vol, translated from the Russian by the Israel Program for Scientific Translations, a new service location in Jerusalem. The handbook, in two volumes, is the Russian counterpart of the Hansen-Elliott books on binary phase diagrams. Volume I (1959) is 635 English pages in length, and covers approximately 250 binary systems of Ac, Al, Am, Ba, Be, B, and N. Volume II (1962) is 870 English pages in length and covers approximately 350 binary systems of Bi, Dy, Eu, Fe, Ga, Ge, H, Hf, Ho, V, and W. Information given, in addition to the phase diagram itself, can include crystal structures, mechanical properties, physical properties (such as density, electrical resistance, thermal conductivity, and heat capacity), chemical properties, and corrosion resistance. References to the literature are given with the description of each system.

Copies of this translation may be purchased from the Clearinghouse for Federal Scientific and Technical Information (U.S. Department of Commerce, Springfield, Va. 22151) at \$9.48 for Volume I and \$11.88 for Volume II.

ASTM Special Committee on Numerical Reference Data

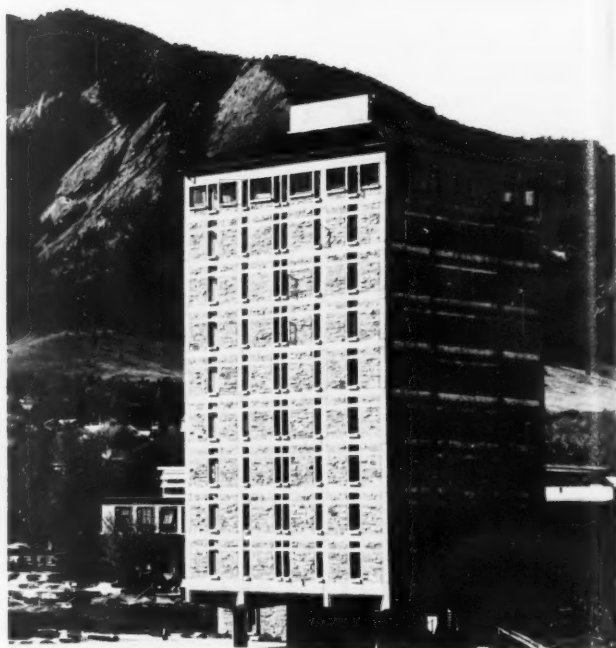
The American Society for Testing and Materials has established a Special Committee on Numerical Reference Data which is responsible for providing awareness and advice in the area of numerical data for science and technology to the Board of Directors of ASTM. The Committee meets about twice a year. Represented on the Committee are industrial organizations, professional societies, compilers of numerical information, users of numerical information, and specialists in various aspects of communication processes. The Committee met at the National Bureau of Standards at Gaithersburg, Md., on April 4 for its spring meeting. Prior to the meeting, visitors were given a brief tour of the Bureau's Gaithersburg facility.

Viscosity and Thermal Conductivity of Mixtures in the Gaseous and Liquid States

The Office of Standard Reference Data has initiated a project with Northwestern University, under the direction of George Thodos, for the compilation and critical evaluation of data on the viscosity and thermal conductivity of mixtures in the gaseous and liquid states.

¹ See listing in NSRDS News, Tech. News Bull. 51, No. 6 (June 1967).

JILA DEDICATES NEW FACILITIES



JILA's new \$2 million building at the University of Colorado in Boulder.

■ Dedication of a new \$2 million building for the Joint Institute for Laboratory Astrophysics (JILA) took place at the University of Colorado in Boulder on April 7, 1967. The ceremony, held in the foyer of the new building's tower, was preceded by a dedication luncheon in the University Memorial Center, and was followed by an openhouse.

JILA was established in 1962 as a cooperative institute of the University of Colorado and the National Bureau of Standards. It is a center for advanced research, study, and graduate education in astrophysics, atomic physics, aerodynamics, and related fields. JILA activities were brought under one roof for the first time last October when Institute scientists and staff members moved into the new building.

Robert L. Sproull, vice president for academic affairs at Cornell University, gave the dedication address at the luncheon. Dignitaries attending the luncheon included: John Love, Governor of Colorado; J. R. Smiley, president of the University of Colorado; A. V. Astin, NBS Director; members of Colorado's State Legislature; and the Board of Regents of the University.

The new building forms the base of an L-shaped complex of structures that house JILA and the Laboratory for Atmospheric and Space Physics, and will eventually house the University's Department of Physics and Astro-

physics. The building is comprised of three sections: A 10-story office tower, a laboratory wing, and an auditorium. The tower contains seven floors of offices above the first-floor, glass-enclosed lobby. It also has a floor with a reading room and seminar facilities, and another housing the mechanical equipment for the tower.

A subbasement lying some 20 feet below the surface of the ground in front of the building contains a spectroscopy laboratory. This special laboratory was constructed in such a way as to prevent mechanical vibrations from interfering with experiments.

Thirty-one laboratories line the halls of the laboratory wing. This wing has two floors above the ground and a basement. It also houses instrument, electronics, and special techniques shops in which much of the precise apparatus used in the experimental program is made.

The auditorium seats 155 and is situated at the northwest corner of the building.

The \$2 million cost of the JILA building was met through a \$900,000 grant from the National Science Foundation and \$1.1 million in borrowed funds to be repaid from research overhead and rentals. The building has 74,900 gross square feet, 41,000 of which are assignable. Its native stone finishing blends with other recent construction on the campus. Harry Weese and Associates, Chicago, was architect for the building.

PUBLICATIONS of the National Bureau of Standards*

PERIODICALS

Technical News Bulletin, Volume 51, No. 6, June 1967. 15 cents. Annual subscription: \$1.50. 75 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

Journal of Research of the National Bureau of Standards

Section A. Physics and Chemistry. Issued six times a year. Annual subscription: Domestic, \$5; foreign, \$6. Single copy, \$1.

Section B. Mathematics and Mathematical Physics. Issued quarterly. Annual subscription: Domestic, \$2.25; foreign, \$2.75. Single copy, 75 cents.

Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: Domestic, \$2.75; foreign, \$3.50. Single copy, 75 cents.

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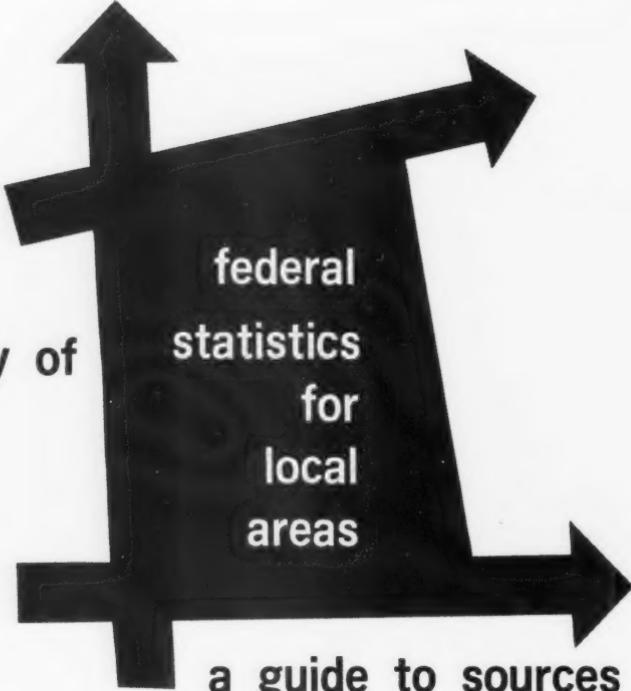
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